

Application No. 10/809,667  
Docket No. 56681.US/4978.5

**R E M A R K S**

Claims 1-42 are in the application. The specification is amended and claims 1 and 17 are amended to more clearly and distinctly claim the invention. Support for the amendment to claims 1 and 17 can be found in the specification on page 13, lines 4-6. No new matter is entered into the case by the amendment.

In the Office Action, a restriction requirement was made between claims 1-11 and 17-27 (Group I) drawn to a process for making fibers and yarns in class 264, subclass 172.13; and claims 12-16 and 28-42 (Group II) are drawn to fibers and yarns in class 428, subclass 37. In response to the restriction requirement, applicants elected the Group I claims (claims 1-11 and 17-27). Applicants hereby affirm this election. This election was made solely for the purpose of advancing prosecution in the case and was made with traverse.

Also, in the Office Action, the specification was objected to for failure to include proper continuing data and for a non-descriptive title. Claims 1-11 and 17-27 were rejected under 35 U.S.C. §102(b) as being anticipated by U.S. Patent No. 5,811,040 to Mallonee and under 35 U.S.C. §103(a) as being unpatentable over the '040 patent. The rejections under 35 U.S.C. §102(b) and §103(a) are respectfully traversed.

With regard to objections to the specification, applicants have amended the title as requested. Applicants are not claiming priority to the patents listed on page 1 of the specification. They are merely calling attention to the fact that there is a common inventor and that this application is related to the other patents as an improvement thereon. Hence, the listing of patents is merely intended to be background information. As such, Applicants are at a loss as to how to appropriately correct this information. The examiner's suggestions in this matter would be greatly appreciated.

A. **The Restriction Requirement Is Improper And Should Be Withdrawn.**

Applicants respectfully submit that the requirement to restrict the claims made in this case is improper. The claims as grouped by the examiner are sufficiently related that their respective classes and subclasses would be thoroughly cross-referenced, and

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essentially the same classes and subclasses would have to be reviewed regardless of which group was examined.

When searching the Group I claims for prior art relating to claims directed to a process for making fibers and yarns having an exterior surface substantially devoid of fibrils, the examiner will undoubtedly have to search art related to the yarns of the Group II claims having the characteristics indicated. Likewise, when searching the Group II claims for subject matter directed to the yarns having certain characteristics, the examiner will have to search art relating to methods for making such yarns and fibers called for in the Group I claims. As described in more detail below, the yarns having the claimed characteristics are made by selecting certain capillary depth to capillary hydraulic diameter (L/D) ratios. Applicants therefore disagree that the yarns can be made by the processes described by the examiner.

It is therefore evident that examination of the Group I, and Group II claims in separate applications will result in duplication of effort since the same classes and subclasses should be searched regardless of which claims are elected. Such duplication of effort is wasteful of Patent Office manpower and resources and it also needlessly increases the cost to the public in obtaining patent protection for closely related inventions or for applications which contain claims of overlapping scope.

Moreover, restriction is not "required" by 35 U.S.C. § 121 as suggested by the Examiner. Congress wisely gave the Commissioner the "discretion" to require restriction. According to 35 U.S.C. § 121 "... the Commissioner may require the application to be restricted...." (emphasis added). The MPEP § 803 lists two criteria that must be present for restriction to be proper:

- 1) The inventions must be independent or distinct; and
- 2) There must be a serious burden on the Examiner if restriction is not required (emphasis added).

The Examiner has not shown any serious burden if examination of all of the claims is conducted at one time. Applicants therefore urge the examiner to reconsider

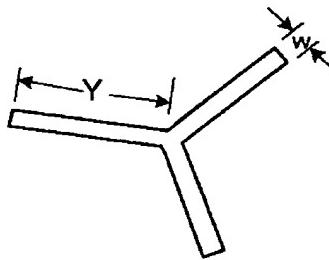
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this matter, withdraw the restriction requirement, and proceed with examination of Claims 1-42 in this application.

B. Claims 1-11 and 17-27 Are Not Anticipated By The Cited Reference.

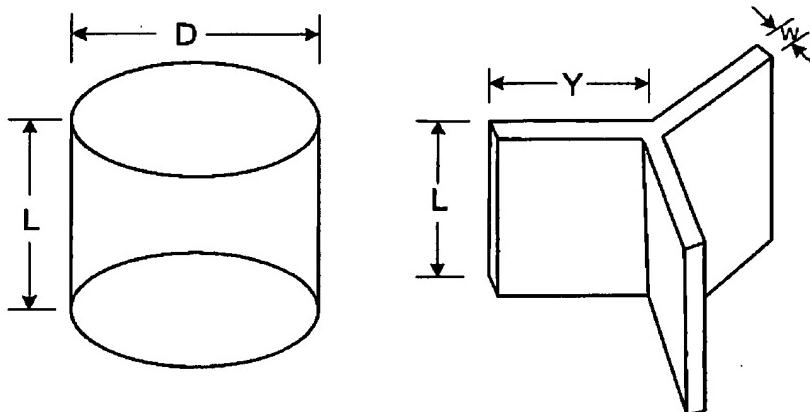
In the rejection of claims 1-11 and 17-27, the examiner relies on the '040 patent to Mallonee. However, for the '040 patent to anticipate the claims, every limitation of the claims must be found in a single reference, either explicitly or inherently.

Applicants have unexpectedly found that the depth to hydraulic diameter (L/D) ratio is a very important parameter for selecting the position of the nylon fibrils with respect to the bulk filament cross-section. In particular, proper selection of a suitable L/D ratio, as claimed, can be used to substantially reduce the presence of nylon fibrils on the exterior surface of each filament, as demonstrated by Figures 5-8 and Example 6. Applicants submit that this important depth to hydraulic diameter ratio (L/D) is not taught, suggested, disclosed in the '040 patent. The L/D ratio referred to by the examiner in the examples of the '040 patent relate to the leg widths (W) and leg lengths (Y) of the trilobal capillary openings as shown by the following sketch:



By contrast, the depth to hydraulic diameter (L/D) ratio in the claims is defined in the specification according to the following sketches:

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wherein L is the depth of the capillary and D is the hydraulic diameter, or diameter, in the case of circular capillaries. In the case of trilobal capillaries, D is calculated from Y and W.

The only mention of an L/D ratio in the '040 patent is with respect to the dimensions of the fibrils obtained by the process described in the examples of the '040 patent. Accordingly, it is clear from the above sketches and the specification that the L/D ratio limitation in claims 1-11 and 17-27 is not taught, suggested or disclosed in the '040 patent, either literally or inherently. Since the '040 patent fails to teach suggest or disclose all of the limitations of the claimed invention, the rejection of claims 1-11 and 17-27 is wholly untenable and should be withdrawn.

C. The Rejection of Claim 1-11 and 17-27 Over The Cited Reference Is Untenable.

In the §103(a) rejection of claims 1-11 and 17-27, the examiner again cites the '040 patent. The failure of the '040 patent to suggest or disclose the important depth to hydraulic diameter ratio (L/D) is described above and is incorporated herein by reference thereto. In fact, the '040 patent provides that the shear rate is the key parameter to achieve the claimed yarn characteristics. However, as set forth in more detail below, one skilled in the art knows that the shear rate depends only on polymer viscosity and on the capillary equivalent diameter and the shear rate is totally independent of the capillary depth to hydraulic diameter ratio L/D. Accordingly, the assertion that it would have been

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obvious to one skilled in the art to optimize the L/D ratio is wholly untenable since the '040 patent is silent with respect to this important parameter.

More specifically, it is well known in the art, that the shear rate  $\gamma$  referred to in the '040 patent is related to the capillary cross-sectional area S and to the capillary perimeter by the formula:

$$\gamma = Q \lambda P / (8 S^2)$$

wherein, for hollow spinnerets S and P are defined by the values of the capillary diameter D as follows:

$$S = \pi D^2 / 4 \text{ and } P = \pi D$$

and for a trilobal spinneret S and P are defined by the capillary leg length A and capillary leg width W as follows:

$$S = 3 A W \text{ and } P = 3 (W+2A)$$

The same scientific literature demonstrates that the shear rate  $\gamma$  is not related to the capillary depth (L). (See the attached article entitled "Spinnerette Design Calculations for Melt Spinning," by Dr. Dan D. Edie, Fiber Producer, April 1979, pp. 40, 42 and 69.

In fact, it is well known by those skilled in the art that the parameter L/D (capillary depth L to capillary equivalent diameter D) is responsible only for the pressure drop along the capillary and does not influence the polymeric flux inside the capillary. ("Spinnerette Design Calculations for Melt Spinning," Ibid.)

The '040 patent is silent about the effect of L/D on the distribution of fibril forming polymer inside a single fiber of bi-component yarns, such as a fiber composed of a polyolefin matrix and containing a plurality of nylon fibrils embedded in the polyolefin matrix. Likewise, the examiner has not cited any references which support the assertion that one skilled in the art would be motivated to optimize the L/D ratio to achieve the important, unexpected results achieved by the claimed invention. Accordingly, since the examiner has failed to make out a *prima facie* case of obviousness, the §103(a) rejection of claims 1-11 and 17-27 should be withdrawn.

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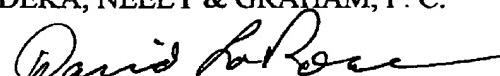
In view of the foregoing amendments and remarks, it is respectfully requested that the amendment be entered and that rejections of claims 1-11 and 17-27 be withdrawn, and that claims 1-11 and 17-27 be allowed.

In the event this response is not timely filed, Applicants hereby petition for the appropriate extension of time and request that the fee for the extension, along with any other fees which may be due with respect to this paper, be charged to our Deposit Account No. 12 2355.

Respectfully submitted,

LUEDEKA, NEELY & GRAHAM, P. C.

By:



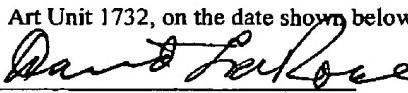
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\* \* \*CERTIFICATE OF FACSIMILE TRANSMISSION\* \* \*

I hereby certify that this correspondence is being facsimile transmitted to the Patent and Trademark Office at 571-273-8300, Attn: Examiner Leo B. Tentoni, Art Unit 1732, on the date shown below.

on October 11, 2005

  
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# Spinnerette Design Calculations for Melt Spinning

By Dr. Dan D. Edie  
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One of the most critical points of a fiber process is polymer extrusion. Not only is filament shape and uniformity determined at this point but this stage of the process also determines much of the subsequent fiber orientation, crystallinity and thus its physical properties. To permit fiber uniformity, proper spinnerette design is essential.

An excellent article on fabrication of entire spinnerette plates appeared in the December 1978 issue of *Fiber Producer* (1)\*. In the April 1978 issue Langley (2) discussed spinnerette fabrication techniques and related problems. This article will cover the calculations required for sizing the extrusion holes within the spinnerette. Design of a properly sized spinnerette hole for your process does not have to be the "black art" that it has become in many companies. A simple knowledge of fluid flow and the rheology of your polymer will usually allow you to calculate the proper spinnerette hole size.

In the April 1978 issue (3) we discussed the importance of having a flow curve (shear stress vs shear rate) for your particular polymer. We also found that nylon and polyester (as well as nearly all melt spun polymers) are non-Newtonian, pseudoplastic fluids. In other words, the viscosity is not constant with shear rate. The original data flow curve (wall shear stress versus apparent wall shear rate) obtained by capillary rheometer tests on fiber quality nylon 6 is shown in Figure 1. If the nylon 6 were a Newtonian fluid, the curve would have a slope equal to one.

The slope of the flow curve in the

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behaves more "non-Newtonian" during extrusion than it did during flow through the manifold. This is common to nearly all melt spun polymers.

We will assume that over a range of apparent wall shear rates,  $\gamma$ , the shear stress at the wall,  $\tau$  is given by Figure 1 and that this relationship holds for any spinnerette hole shape used to extrude the polymer.

## Spinnerette Design for Circular Filaments

In most processes a circular filament is desired, so circular spinnerette holes are the most common. If flow is steady and the capillary is sufficiently long so that end effects can be neglected, we could use Equation 1 to calculate the apparent shear rate at the wall of the capillary.

$$\tau = \frac{4Q}{\pi R^3} \quad (1)$$

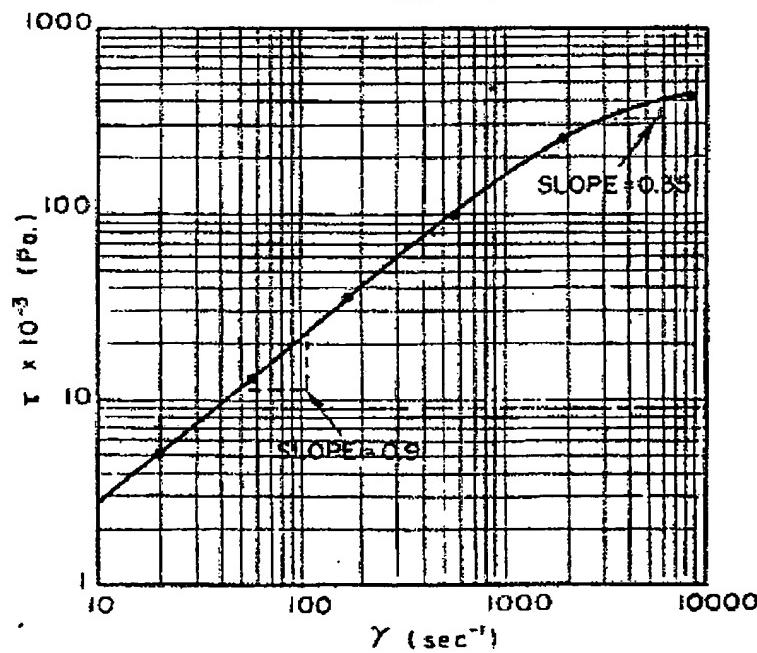


Figure 1. Flow curve for fiber quality nylon 6.

\*Numbers in parentheses refer to references or the end of article.

where:

$Q$  = flow rate through the capillary,  $\text{m}^3/\text{sec}$

$R$  = radius of the capillary, m

For a Newtonian fluid the pressure drop across the capillary (and thus the spinnerette) would be given by

$$\frac{\Delta P}{R} = \frac{212}{\mu L}$$

where:

$\tau$  = shear stress at the capillary walls (for a Newtonian fluid  $\tau = \mu \dot{\gamma}$ )

$\mu$  = Pa

$\mu$  = Newtonian viscosity, Pa·sec

$L$  = length of capillary, m

$\Delta P$  = pressure drop across the capillary, N/m<sup>2</sup>

For a non-Newtonian fluid, such as most polymer melts, we could fit the shear stress,  $\tau$ , in equation 2 to reading it from the flow curve at the previously calculated value of the parent wall shear rate.

Therefore, if we wished to spin  $1.4 \times 10^{-8} \text{ m}^3/\text{sec}$  per capillary hole, a  $1.5 \times 10^{-4} \text{ m}$  capillary radius would give a shear rate of

$$\dot{\gamma} = \frac{4(1.4 \times 10^{-8} \text{ m}^3/\text{sec})}{\pi(1.5 \times 10^{-4} \text{ m})^2} =$$

$$5,282 \text{ sec}^{-1}$$

which would be well below a typical critical apparent shear rate for fiber fracture of about  $10,000 \text{ sec}^{-1}$ . At this apparent shear rate the flow curve (Figure 1) gives a shear stress of  $2 \times 300,000 \text{ Pa}$ .

The pressure drop across the spinnerette would be (for a capillary length of  $4.0 \times 10^{-3} \text{ m}$ )

$$\Delta P = \frac{2(4.0 \times 10^{-3} \text{ m})(300,000 \text{ Pa})}{(1.5 \times 10^{-4} \text{ m})}$$

$$\Delta P = 1.6 \times 10^7 \text{ Pa} = (2320 \text{ psi}).$$

We have neglected end effects, but for the L/D of this capillary (Table 13) this simple calculation will still give a good estimate.

#### Spinnerette Design for Non-circular Filaments

As Schwab (1) pointed out, non-circular filaments are spun on many synthetic fiber processes which start with a natural fiber. Capillary flow calculations for the required non-circular

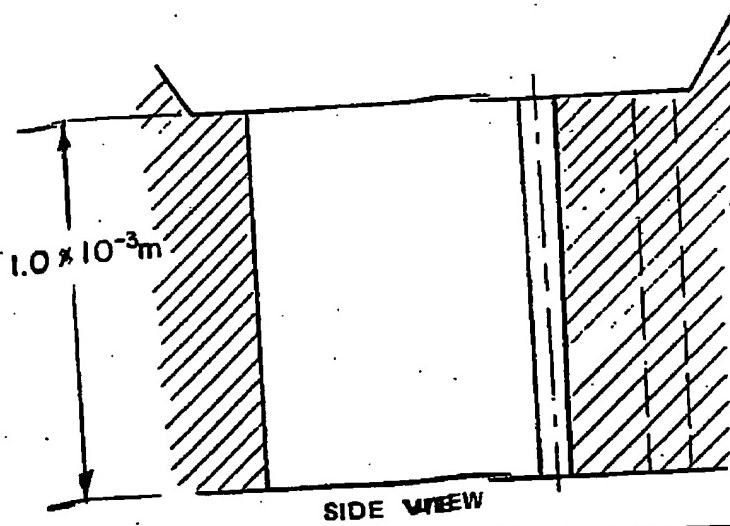
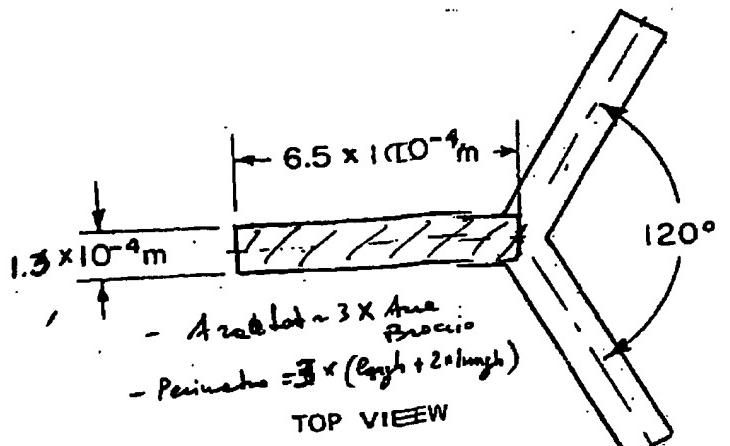


Figure 2. "Y" shaped hole used for non-circular fibers.

spinnerette holes are much more complex. Nevertheless, a momentum balance can be made over the capillary and either an analytical or a numerical solution made to predict shear rates and pressure drops over these non-circular holes. Articles have recently been published by Miller (4) and Hanks (5) which can be of help to spinnerette designers in giving good approximations to the shear rates and pressure drops found in non-circular shapes. Both Miller and Hanks develop shape factors which can be used in wall shear rate and pressure

drop calculations for flow through non-circular holes.

As one example let's estimate the wall shear rate and the pressure drop for flow of  $1.4 \times 10^{-8} \text{ m}^3/\text{sec}$  of our nylon 6 through the "Y" shaped hole shown in Figure 2. The area,  $A$ , of the hole would be approximately:

$$A = 3(1.3 \times 10^{-4} \text{ m})(6.5 \times 10^{-4} \text{ m}) = 2.54 \times 10^{-7} \text{ m}^2$$

and the perimeter,  $P$ , would be:

$$P = 3(1.3 \times 10^{-4} \text{ m}) + 6(6.5 \times 10^{-4} \text{ m}) = 4.29 \times 10^{-3} \text{ m}$$

Miller derives the shear rate as:

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$$Y = \frac{Q_A}{2 A D_h} = \frac{Q \cdot \lambda \cdot P}{8 A^4}$$

where:

$\lambda$  = a shape factor which changes for each hole geometry  
 $D_h$  = hydraulic diameter =  $\frac{4A}{P}$ , m.

For our spinnerette the hydraulic diameter,  $D_h$ , is

$$D_h = \frac{4(2.54 \times 10^{-7} \text{m}^2)}{4.29 \times 10^{-3} \text{m}} =$$

$$2.36 \times 10^{-4} \text{m}.$$

For rectangles (each leg of our Y shaped hole is a rectangle) Miller derives the shape factor as:

$$\lambda = \frac{24}{[(1 - .351 k)(1 + k)]^2} \quad (4)$$

where:

$k$  = width to length ratio of hole.  
 Miller (4) also lists shape factors for other hole shapes.

For our hole  $k = (1.3 \times 10^{-4} \text{m}) / (6.5 \times 10^{-4} \text{m}) = 0.2$   
 and thus

$$\lambda = \frac{24}{[(1 - .351 (.2))(1 + .2)]^2} = 19.3$$

Therefore, the shear rate within the hole is approximately,

$$Y = \frac{1.4 \times 10^{-6} \text{m}^3/\text{sec}}{2(2.54 \times 10^{-7} \text{m}^2)(2.36 \times 10^{-4} \text{m})} \\ = 2258 \text{ sec}^{-1}$$

Again, this is well below typical critical shear rates for the onset of melt fracture (a phenomenon which gives nonuniform filaments). Miller found the pressure drop would be

$$\Delta P = \frac{4Lr}{D_h} \quad (5)$$

At this apparent shear rate (2258  $\text{sec}^{-1}$ ), Figure 1 gives a shear stress of 190,000 Pa.

Thus, for our non-circular hole

$$\Delta P = \frac{4(1 \times 10^{-3} \text{m})(190,000 \text{ Pa})}{2.36 \times 10^{-4} \text{m}}$$

$$\Delta P = 3.22 \times 10^6 \text{ Pa} = 467 \text{ psi}$$

For an exact solution, end effects would have to be included but the

above calculation would be sufficient for design estimates of shear rate in the capillary and pressure drop across the spinnerette. These calculations are also useful to see how high throughput can be increased with existing spinnerettes before critical shear and thus melt fracture are reached.

### References

1. Schwab, M., *Fiber Producer*, 6 (6), p. 42 (December 1978).
2. Langley, I. L., *Fiber Producer*, 6 (2), p. 14 (April 1978).
3. Edie, D. D., *Fiber Producer*, 6 (2), p. 42 (April 1978).
4. Miller, C., *Ind. and Engr. Chem. Fund.*, 11 (4), 524 (1972).
5. Hanks, R. W., *Ind. and Engr. Chem. Fund.*, 13 (1), 62 (1974).

### Editor's Note:

This topic (as well as general spinnerette material construction and cleaning problems) will be covered in depth in a short course entitled "Spinnerette Design for Melt Spinning," which will be presented by D. D. Edie, I. L. Langley and others on May 24 and 25, 1979, at Clemson University.

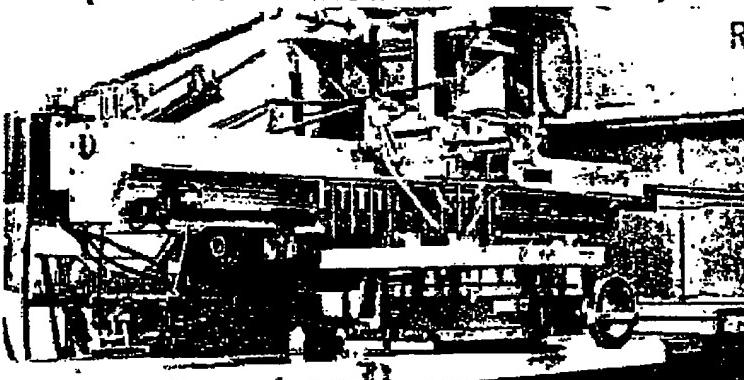
The short course will be jointly sponsored by Clemson University and Fiber Producer magazine. Write the author for further information.

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